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Diagnostics and Methods for Real-Time Laser Microchemistry

Final Technical Report

Period: 1 April 92 - 31 March 93

prepared by
Ehrlich Associates

Final Technical Report: Diagnostics and Methods for Real-Time Laser Microchemistry (Period covered: 1 April 92 - 31 March 93)

Among the of the main goals of the program have been the development of digital real-time microchemical processes and diagnostics. Further objectives have been the design of a stable platform, and the mechanical subsystems and electronic circuits to provide real-time machine control. These will be the basis for the study of control and stabilization methods. Specific subassemblies designed were the massive 1.5- inch-thick steel plate, the mechanical frame support, the vibration isolators, and the sliding cell supports. In addition design of the main control circuits, including those for laser incident-light feed-back, laser reflected light, illumination control, opto-interrupt for vibration isolation and zoom magnification control, have been completed.

Significant accomplishments have also been made in the design of control systems and in the electronics integration for these systems. An important problem has been adressed in the laser power subsystem. The full electronics design for baseline closed loop machine operatiion have been completed.

In addition the full specification for sensors and actuators has been completed and all elements have been identified.

Important advances have been made in the electronic interconnect and control systems for the diagnostics, precision positioning, and optical instrumentation. Significant progress has been made in the design of digitally controlled processes based on the informed adjustment of the process parameters and the solid state laser parameters. The software interface for display of the visual image, machine states, and diagnostic data has been designed.

Finally, further advances have been made in the implementation of required designs for sensor fixturing and for actuators. The portfolio of digital laser processes has been expanded to include contact processes important for multichip modules and printed circuit boards. The sensor and control display interfaces have been designed.

Digital Deposition / Digital Etching

The process of digital laser depostion requires accurate regulation of the laser energy in a pulse-by-pulse basis. Although the solid-state laser chosen for the machine is very reproducible in producing a specified pulse energy after it is reached equilibrated conditions in inversion and heat flow, normal transients cause unacceptable variations of the initial pulses in any irradiation sequence. A solution to these issues has been constructed in which the laser is continuously pumped during machine operation. This establishes constant thermal conditions in the laser rod. During most of the time when there is no need for laser pulses at the workpiece, the laser q-switch is left in the "off" postition so that there is no lasing but rather the pump light is radiated spontaniously from the rod. It is not sufficient to simply turn on the q-switch and call for laser pulses since this leads to large initial pulses as a result of the complete population inversion of full pumping. Instead when pulses are needed, the pump is turned off for several laser storage times (several miliseconds). This time is too short to seriously effect the thermal conditions in the rod. The q-switch is then turned to the "on" state and the pump power is returned to its normal value. The result is a uniform pulse train as required for digital deposition. The digital depostion process is now thought to be at a sufficient state of development for IC repair applictions.

The high repetition rate laser permits an increase of more than one order of magnitude in the rate of deposition by laser chemical vapor deposition. An important discovery is that, due to laser nonlinearities, the improvement is faster than would be predicted by the simple scaling of pulse rate. The advantage is critical for applications, particularly in electronic packaging. We have now completed target process and parameter specifications for the following processes:

(a) metallization cuts by ablation
(b) metallization cuts by melt back
(c) Laser deposition of platinum, aluminium, gold and copper from the vapor phase
(d) Via formation in silicon nitride and silicon oxide passivation layers
(e) Via formation in polyimide

We have now completed target process and parameter specifications for the following additional processes:

(f) electrical contact formation to first surface copper metallization

(g) electrical contact formation to buried copper metallization

Massive Plate

This is the support for the laser and optical system and includes more than 140 carefully located tapped holes. The weight provides sufficient momentum to damp floor vibration when the plate is suspended on four air bladders. Damping must be sufficient to reduce relative internal vibration of the optical assemblies to submicrometer in-plane and out-of plan residual motions.

Mechanical Support Frame

This is the overall mechanical support assembly and includes allowances for containing all electronic and vacuum subsystems. The construction is welded from custom parts, all of which have been designed in this period. Three-dimensional layout of the frame was carefully optimized in order to minimize the volume, as small tool size is seen as critical for the acceptance of the technology.

Vibration Isolators and Opto-interrupts

These suspend the plate and and provide feed-back to level it. Custom parts were designed for these subassemblies.

Cell Mounting

The vacuum-cell fixturing includes provision for later incorporation of heaters and electronic test. Space is provided for future monitors. Attention has been given to mechanical stability. This assembly is pneumatically driven.

Incident and Reflected Laser Feedback Circuits

These circuits read fast photodiode signals for the incident and reflected light sensors. The laser also has an integral pump-power control but this alone is seen as inadequate for the tight control needed on wafers, and also can not be used to compensate for variation in reflectivity across the wafer.

Zoom lens, and Illuminator Circuits

These control circuits are needed to provide a easily manipulated video image of the integrated circuit. The digitized video image is the basis for the x,y,z motion control and navigation systems.

Opto-Interrupter Circuits

These monitor the four supports of the massive plate. Air is directed as needed to the pneumatic supports.

Sensor Systems Interconnection

The full laser and motion systems entail several hundred wire connections between the sensors, encoders, motion and light control systems, etc. The full design of the cabling to impliment these electronic connections has been developed in this period.

Incident and Reflected Laser Feedback Diagnostics

Circuits were designed in the last period to read fast photodiode signals for the incident and reflected light sensors. These have now been incorporated into the full control systems and are included in the full process and machine design. The need for a sensitive reflected-light monitor to automatically control laser exposure during the via making process in IC restructuring has been confirmed. Manual visual diagnostics lead to frequent over exposure. The reflected light monitor needs to be sensitve to changes as small as several percent. This sensitivity should be achievable with our circuit designs.

CCD Imager Control

Fast methods for implimenting control of autofocus and autoposition, based on data taken directly from the digitized CCD camera image, have been developed in this period.

Position Sensors

Depending on stage options there are to be 5 or 7 position encoders. These are x,y,z linear encoders, each 100 lines per millimeter with 32x interpolation, plus (with the lead screw stage option only) supplementary x,y rotary encoders. In addition there will be rotary encoders for for cell rotation and for the z axis focus control (both Newport Co.).

Laser/Optics Sensors

Sensors will provide continuous monitoring of laser pump power, laser repetition rate, laser output power, and laser reflected power. The first two of these are integral to the Spectra Physics 7300 laser. The second two are silicon photodiodes with custom circuits designed by Ehrlich Associates.

Vacuum Sensors

A silicon diaphragm sensor monitors cell pressure. Pump foreline pressure is monitored with a standard thermocouple gage. A anhydrous silica toxic vapor trap has been designed which has input and output temperature sensors. Since the trap generates heat under normal operation. The temperature difference between these sensors indicates the safe operation of the trap. Future options are to monitor liquid level in the reservoir or reservoir pressure with a silicon diaphragm gauge.

Interlocks

Software interlocks are provided on cell lid position, port door position, and camera protect filter position.

Vibration Control

Optointerrupters designed by Ehrlich Associates will be at each of the four supports for the massive plate. These are used to command refills to the Barry Control Inc.float supports.

Drive Actuators

The x,y drive actuators chosen are linear motors supplied by Anorad Co. or equivalent. A DC motormicrometer (e.g., Newport Co.) is chosen for z control. A built in DC motor (Newport Co.) controls the rotary stage.

Optics Actuators

Galvanometers control the laser shutter, and camera protect filter. The zoom lens (DO Industries) has a built-in DC motor drive. A pneumatic actuator mechanism designed by Ehrlich Associates is used to change between objective lenses.

Vacuum/Mechanical Actuators

Solenoid controlled (24 Volt Kip) valves are used on cell inlet, cell outlet, and cell purge vacuum lines. Pneumatic fixtures have been designed by Ehrlich Associates for the cell slider, lid lifter, and front door.

Sensor Interconnection, Cabling, and Laser control

Sensor interconnection via hardwired electronics and software has been addressed in this period. The hardwired interconnections have been designed and the computer boards to fit into a 386 type PC have been identified. This has required the organization of more than one hundred separate conductor paths. The sensor and machine functions require a video board, a 4-axis motion control board, several analogue to digital connvertors, a clock generator, and custom circuits to control illumination of a zoomed optical system. A critical problem addressed was the issue of start-up transients for the laser control. Use of the laser as supplied by the manufacturer (Spectra Physics Inc.) results in a abnormally large first pulse as the q-switch is switched to dump the laser cavity. This transient is disastrous for digital processing since it is not well controlled, usually falls outside the process window, and frequently leads to major substrate damage. This problem was solved by designing a rapid ramping control for the laser pump power. The laser pump is ramped after the q-switch is turned on. A further improvement is to provide a separate computer-controlled pulsing circuit by-passing the original Spectra-

Physics controller. This allows laser pulse repetition frequencies up to 100 kHz. We have found that although the pulse energies diminish at the higher rates, we can nonetheless achieve important process advantages using the laser with lower stored energy.

Software and Display Interfaces

The interfaces and organization of sensor and control systems has been designed. This is to be implemented under a Windows 3.1 environment.

Sensor Fixturing and Actuator Designs

We have finished design of fixturing for sensors and diagnostics as identified in previous contract periods. This includes machine drawings for 6 mechanical parts and part modifications for the optical imaging and laser control systems. We have also designed parts for automated pneumatic control of the vacuum chamber and vacuum pumping system. Design of the pneumatic systems has also included air flow control through the use of flow restrictors.

Software and Display Interfaces

We have begun to implement display interfaces and organization of sensor and control systems. To be included are:

(a) incident laser power
(b) reflected laser power
(c) pump power
(d) live video image
(d) positioner control data, velocities, real-time position reading to 0.2 μm, instructed next move
(e) vacuum pressure, vacuum system state, valve positions
(f) focus position, real time z position to 0.1 μm

signed

Daniel Ehrlich, President
Ehrlich Associates